Materials Analysis with Magnetic X-Ray Circular Dichroism

Unraveling the mysteries of new magnetic materials

The last several years have witnessed extensive growth in the research and development of nanoscale magnetic materials. Three general trends can be observed:

1. Magnetism is one of those special cases in which fundamental research can lead directly to technological applications.

2. The key to understanding and manipulating magnetic properties is the subtle yet overwhelming interplay of atomic geometric structure and local magnetic properties. For example, the giant magneto-resistance effect (GMR) appears to be intimately coupled to interfacial and thin-film effects and probably will require elementally specific probes for an explicit determination of its underlying causes. This also appears to be the case for spin valves, which with GMR may be a source of device miniaturization in read heads and magnetic sensors.

3. The importance of probes with a direct spin dependence.

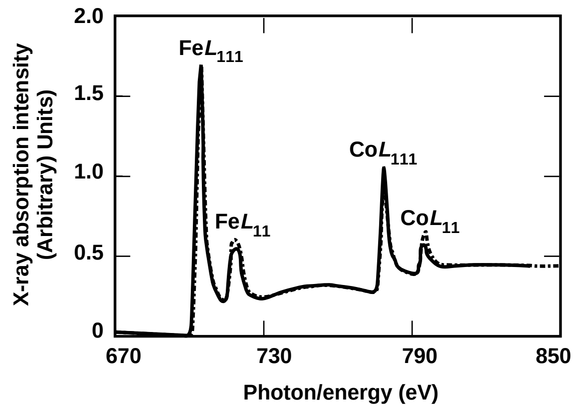
Element-specific probe of magnetization and magnetic structure

In response to these observations, we have developed the x-ray analog of magneto optics as an element-specific probe of magnetization and magnetic structure. Based on the interaction of circularly polarized synchrotron radiation and the tightly bound core states of individual elements, these techniques allow us to address issues in composite systems and multilayer samples on an element-by-element basis.

APPLICATIONS

- *Element-specific determinations of magnetic moments, both spin and orbital components*
- *Powerful probe of composite and multilayer magnetic systems*
- *Characterization of GMR and spin-valve systems*

An example of elemental specificity and magnetic sensitivity can be seen in the figure. Here, iron and cobalt can be separately interrogated. Both elements are exhibiting a magnetic polarization, that is, a dichroism with x-ray circular polarization. From measurements like these, we can extract element-specific magnetic moments, both orbital and spin components. We can also ascertain the degree of externally imposed polarization on normally nonmagnetic layers—an issue crucial in spin valve and GMR systems. Thus, it is the combination of both elemental specificity and magnetic sensitivity that will be essential to unraveling the mysteries of such new magnetic materials and will pave the way for their full technological exploitation.



The x-ray absorption spectra of $Fe_{4.7Å}$, $Co_{4.7Å}$, and $Pt_{9.5Å}$, using circularly polarized x rays. The spectra are for a grazing x-ray incidence angle 80° from the sample normal. The solid curve is the result for a nearly antiparallel arrangement of x-ray helicity and majority electron spin, and the dashed curve a nearly parallel geometry. The intensity differences for the L_{11} and L_{111} peaks are apparent.

Technical facilities

Because of reduced vacuum requirements, we can prepare granular and multilayer samples *ex situ* and perform the x-ray measurements with rapid turnaround times. Our research is possible because of the Laboratory's synchrotron radiation facilities at the Stanford Synchrotron Research Laboratory. Beamline 8-2, a spherical grating monochromator optical system, is a very powerful source of soft x rays. A University of California / National Laboratory facility, this beamline has a wide range of capabilities, including the capacity to operate in high resolution or circular polarization modes. Beamline facilities include CoPd multilayers as part of the flux monitor section, which can be used to cross-check the helicity selection.

Contact

James Tobin
Phone: (510) 422-7247
Fax: (510) 423-7040
E-mail: tobin@cms1.llnl.gov
Mail code: L-357

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